Power Budget Extender For EPON

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Agenda

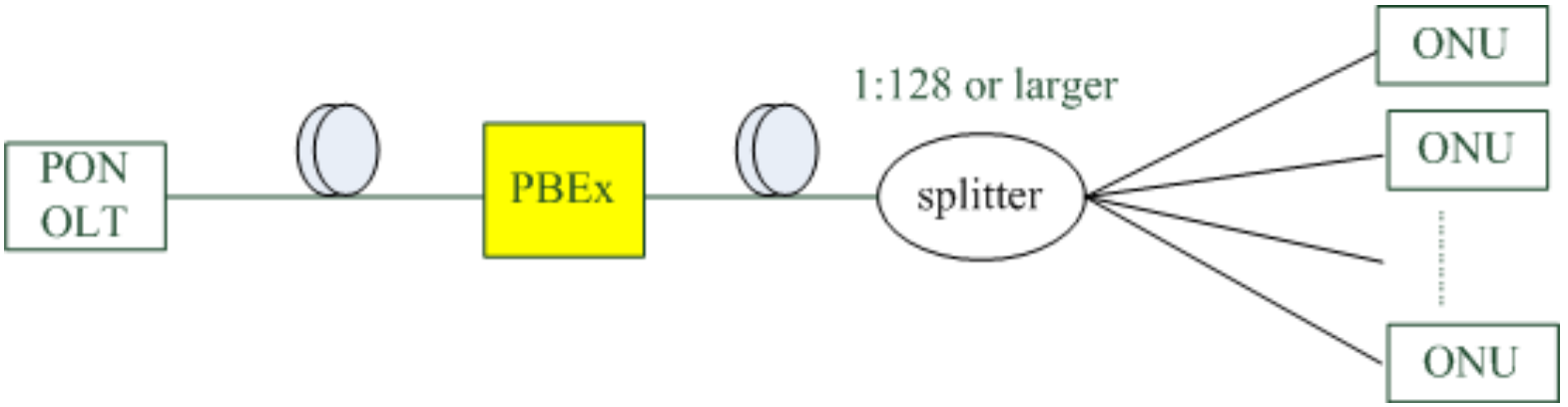
- Background and Overview
- Overview of Power Budget Extender (PBEx)
- PBEx for Coexistence Mode
- Comparison and Proposed Solutions

Background

- 1:64+ Split Ratio
  - Larger split ratio (e.g. 1:128, 1:256 or more) is needed in dense populated metro areas to share OLT port cost among larger number of subscribers
  - The actual installation ratio of EPON is very low at the beginning
    Several PON ports need to be combined to increase the efficiency of OLT port
- Longer Reach
  - Longer reach is needed under some circumstances (see slides from CFI and SG meetings)
- Reduce the cost
  - The OPEX cut down is desired as well as expansion of service areas
- Review
  - Power budget of 24 dB is defined in 802.3ah to support 20 km @1:16
  - Power budget of 29 dB is defined in 802.3av to support 20 km @1:32
  - Power budget of 33 dB to support 20 km @1:64 is under discussion in 802.3bk
  - Power budget beyond 33 dB can't be satisfied just now

Solutions

- Optical loss budget of 33 dB or less can be achieved in a cost-efficient way by increasing the Tx launch power and/ or improving Rx sensitivity or adding FEC to PCS
- PBEx is a preferred choice when optical loss budget needs to be increased considerably above 33 dB



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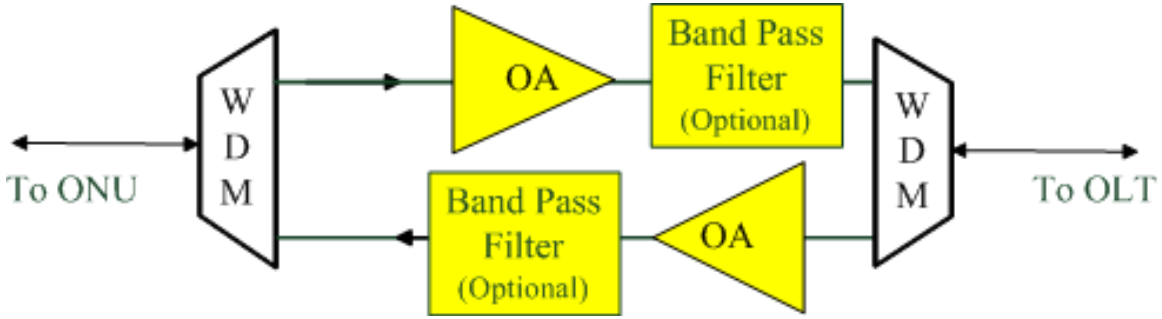
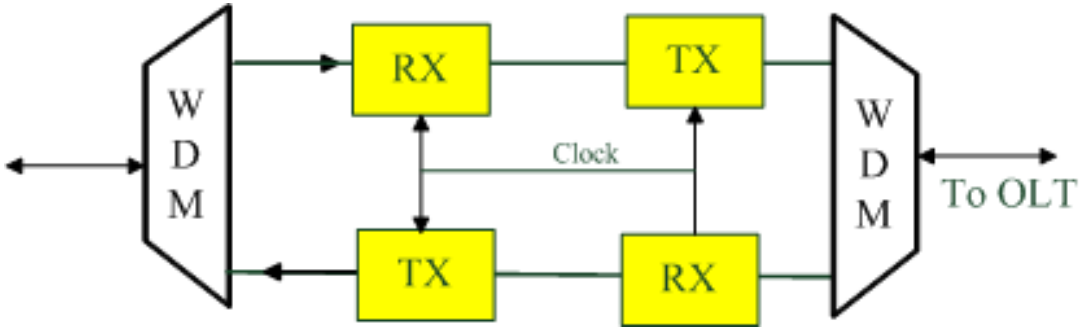
Optical Amplifier

- **Semiconductor Optical Amplifier (SOA)**
  - O-band, S-band are commercially available
  - O-band SOA with gain bandwidth of 100 nm is available, it is a good choice for both 1G and 10G EPON upstream signal amplification since its good support for burst mode signals
  - High noise figure
- **Optical Fiber Amplifiers**
  - Erbium-Doped Fiber Amplifier (EDFA):
    C or L band is commercially available
    L-band EDFA is a good choice for 10G-EPON downstream amplification
    EDFA doesn't support upstream burst mode signals well since its long settling time
  - Praseodymium-Doped Fiber Amplifier (PDFA) : O-band, under experimental study
  - Thulium-Doped Fiber Amplifier (TDFA) : S-band, under experimental study
- **Fiber Raman Amplifier (FRA):** Distributed FRA and Discrete FRA
  - O-band, C-band, S-band or L-band are theoretically available
  - Bandwidth can reach up to 100 nm
  - FRA is installed in the central office, which keeps the ODN passive
  - Power of several to tens of watts is required for Discrete FRA and 500 mW or more is required for Distributed FRA

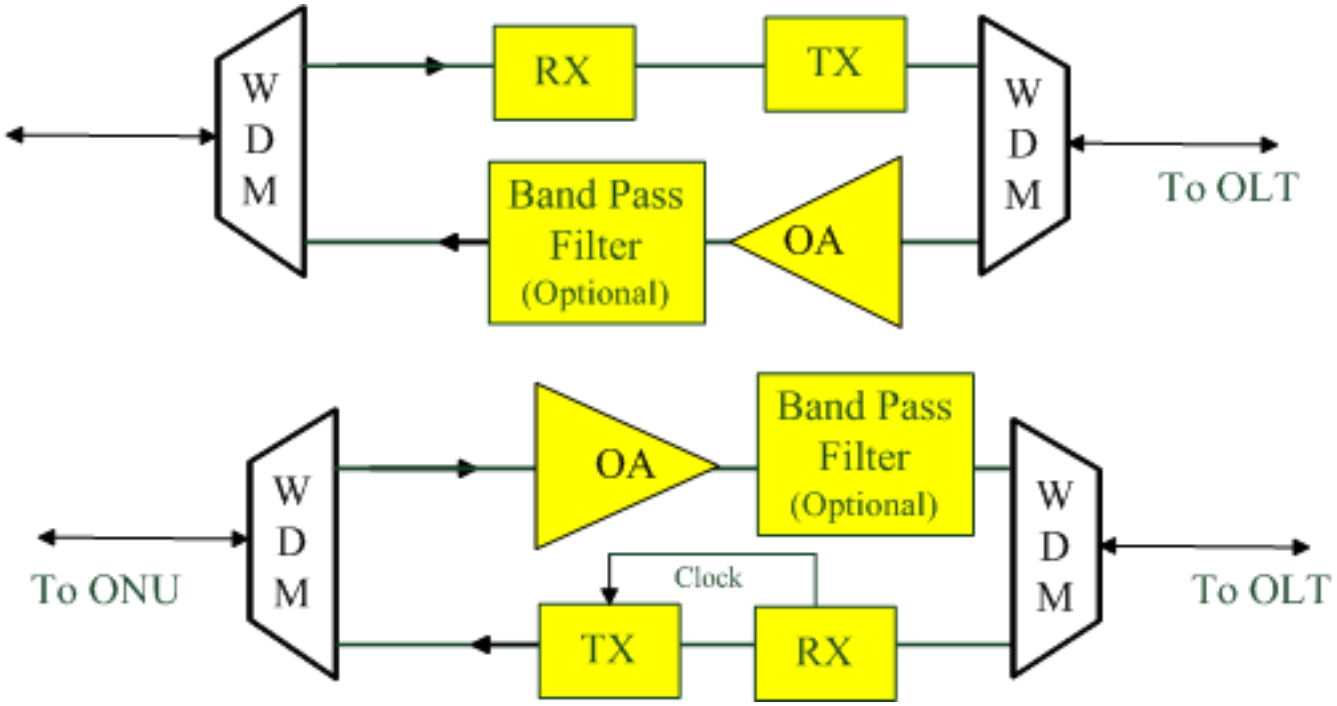


OEO Regenerator

- From the signal point of view
  - **2R (Re-shaping, Re-amplification):**
    Low power consumption, but may can't satisfy long reach requirement because of the accumulated jitter induced by the light dispersion in the fiber
  - **3R (Re-shaping, Re-timing, Re-amplification):**
    Low jitter, but power consumption is higher due to extra re-timing function
- From the MAC point of view
  - **Bit-level regeneration (Preferred):** Simple to implement, but OLT transceiver providing the qualified LOS or SD signal is needed
    Rate select signal of upstream for coexistence mode is a big challenge
    Guard-time and preamble length needed will be longer, but since the value defined in 802.3ah and 802.3av is already very large, the value is most likely to be already large enough
  - **Frame-level regeneration:** The FPGA implementation will be complex and the power consumption will be higher compared to the bit-level regeneration
    But the PBEx is fully transparent to OLT regards to burst mode US, making it a preferred solution for the upstream channel



OEO & OA Hybrid Schemes



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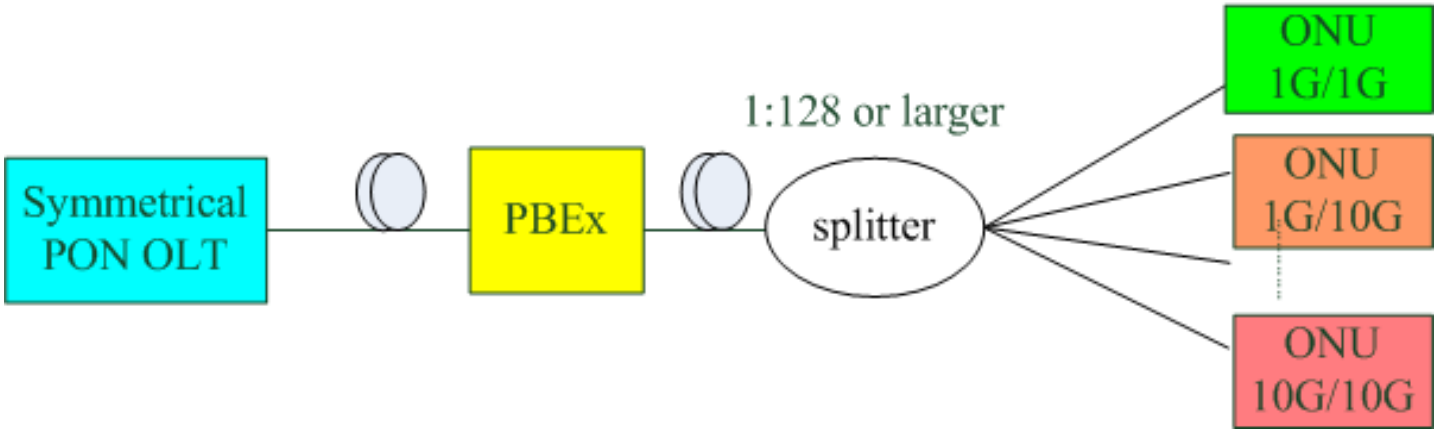
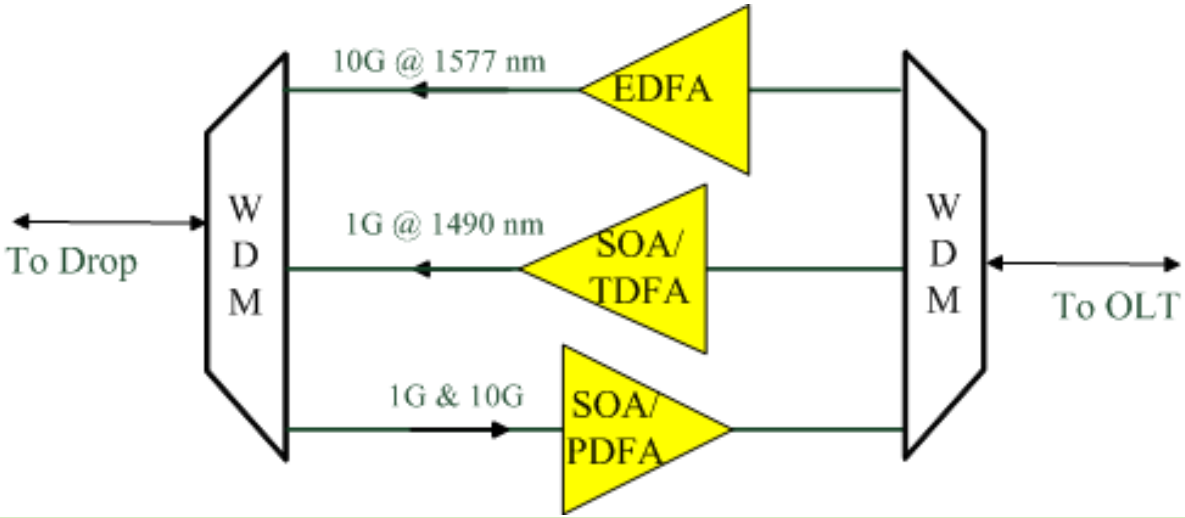
Coexistence Mode

- The PBEx should support 1G-EPON and 10G-EPON coexistence mode with a longer reach and larger split ratio (e.g. 40+ km), with the split ratio of 1:128+



OA Solutions

- Advantages
  - Simple structure and support for data rate transparency
  - The guard-time and preamble length is smaller than the OEO method since its has short settling time
- Disadvantages
  - High cost: price of EDFA and FRA light pump source, Erbium Doped Fiber is also expensive for EDFA. For SOA, limited availability and high unitary price
  - Large size for EDFA



OEO Solutions

- Advantages

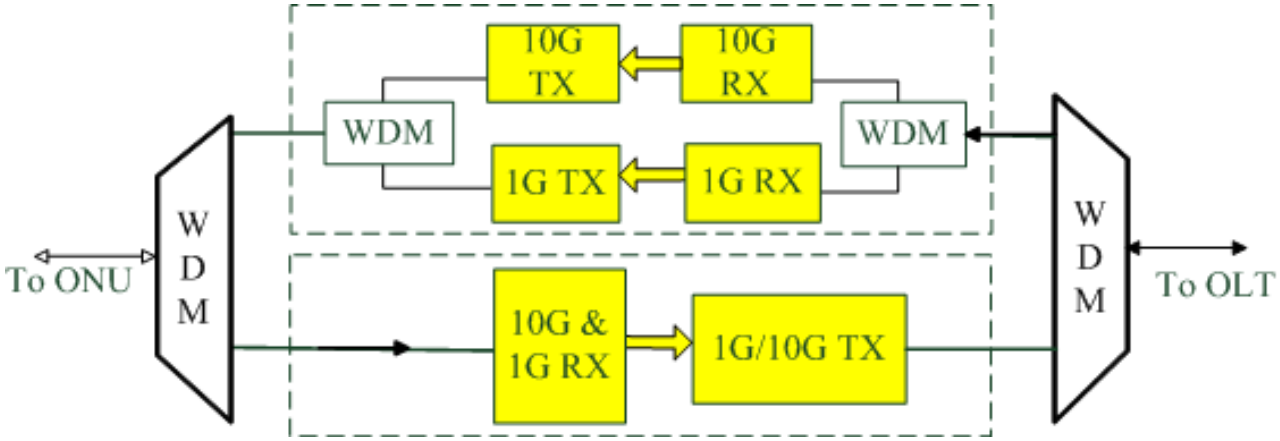
  Low cost, no ASE (Amplified Spontaneous Emission) noise

- Disadvantages

  Generation of the control signal of the upstream on/off switching is a big challenge in EPON (needs tracking of upstream grants)

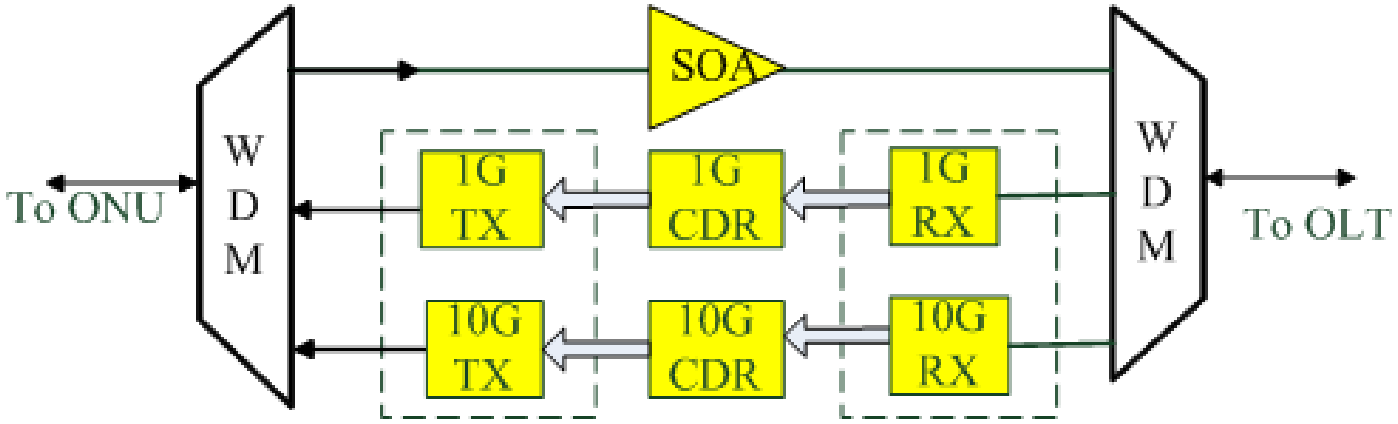
  The guard-time and preamble length needed will be longer than in OA, but may within the value defined in 802.3

  Rate transparency is not supported (not very future-proof)



OA & OEO Hybrid Solutions

- O-Band SOA is a good choice for the upstream optical amplification because of its good support for burst mode signals
- The downstream continuous signal can be handled using the OEO method because of its low cost and demonstrated technical feasibility



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Comparison of different solutions

Items	OEO	SOA	EDFA	Raman
Cost	low	high+	high	High++
Noise	NA	high	low	Very low
Gain	20~30 dB	20~30dB	20~40 dB	<20dB[note4]
Feasibility	high[note1]	high	high[note2]	low
Protocol transparency	bad	good	good[note3]	good
Temperature stability	good	bad	good	very good

Note1: The challenge is the generation of turn on/off signal for coexistence mode
Note2: only C or L band is available
Note3: It doesn't support the upstream burst mode well
Note4: This is for Distributed FRA, while for Discrete FRA 40 dB or above can be obtained

Proposed Solution

- Adopting OEO as DS and SOA as US is the preferred scheme, especially for 10G-EPON and coexistence mode
  - The downstream signal is continuous and easy to be handled by adopting OEO method
  - The upstream signal is burst mode and SOA is a good choice
- Power budget extension
  - The gain obtained by adopting commercially used OA is typically 20dB
  - The power budget can be extended by 20/24/29dB by adopting PR(X)/PX10/20/30 module in OEO, respectively
  - So the total power budget for both direction can reach up to 40/44/49dB which corresponds to over 20 km @ 1:256/512/2048 or 60 km @1:4/16/32, respectively[note5]

- note5: the ASE effect of SOA in the US is not considered here

PMD Layer parameters of PBEx

Items	Unit	Items	Unit
Number of Fiber, Fiber type	-		
Attenuation range for 1480-1500 nm from OLT to PBEx	dB	Maximum attenuation for 1260-1360 nm from PBEx to OLT	dB
Attenuation range for 1575-1580 nm from OLT to PBEx	dB	Minimum attenuation for 1260-1280nm from PBEx to OLT	dB
Attenuation range for 1480-1500 nm from PBEx to ONU	dB	Maximum attenuation for 1260-1360 nm from ONU to PBEx	dB
Attenuation range for 1575-1580 nm from PBEx to ONU	dB	Minimum attenuation for 1260-1280nm from ONU to PBEx	dB
Maximum optical path penalty from OLT to PBEx	dB	Maximum optical path penalty PBEx to ONU	dB
PBEx receiver	-	**PBEx transmitter**	
Minimum Sensitivity for DS 1G signal	dBm	Average launch power (max，min) for DS 1G signal	dBm
Minimum Sensitivity for DS 10G signal	dBm	Average launch power (max，min) for DS 10G signal	dBm
Minimum overload for DS 1G signal	dBm	Average launch power (max，min) for US 1G signal	dBm
Minimum overload for DS 10G signal	dBm	Average launch power (max，min) for US 10G signal	dBm
Minimum Sensitivity for US 1G signal	dBm	Maximum ASE output power in 1255-1365 (for 1G)/1255-1285 (for 10G) nm launched toward OLT relative to signal output power	dB
Minimum Sensitivity for US 10G signal	dBm	Maximum ASE output power in 1200-1255 nm and 1285-1400 nm (for 10G)/1365-1400 nm launched toward OLT relative to signal output power	dB
Minimum overload for US 1G signal	dBm	Maximum ASE output power in 1400-1600 nm band for US	dBm
Minimum overload for US 10G signal	dBm		
Bit Error Ratio	-		

PMD Layer parameters of OLT and ONU

Items	Unit	Items	Unit
OLT transmitter		**ONU transmitter**	
All parameters	same as 802.3ah and 802.3av	All parameters in 802.3ah and 802.3av unless specified here	same as 802.3ah and 802.3av
OLT receiver		Dispersion range (for 10G)	ps/nm
All parameters in 802.3ah and 802.3av unless specified here	same as 802.3ah and 802.3av	**ONU receiver**	
Bit error ratio	-	All parameters	same as 802.3ah and 802.3av
Immunity against incident ASE power (optical power bias tolerance) in 1255-1365 nm band at x dB additional penalty: ASE power relative to modulated signal power	dB	**PBEx timing**	
Additional penalty due to ASE-related power bias at OLT receiver	dB	Maximum SOA settling time	ns

Bringing you Closer

Thanks!